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REMARKS

This Amendment is in response to the Office Action dated February 23, 2005. In the Office Action, the Examiner rejected claims 1, 2, 3, 10, 11, 18, and 19 under 35 U.S.C. § 102(e) as being anticipated by Palm, U.S. Patent No. 6,735,245 (hereinafter *Palm*). Claims 4, 7-9, 12, and 20 were rejected under 35 U.S.C. § 103(a) as being unpatentable over *Palm* in view of Barber et al., U.S. Patent No. 6,799,030. Claims 5 and 6 were rejected under 35 U.S.C. § 103(a) as being unpatentable over *Palm* in view of Barber et al. as applied to claim 4 above, and further in view of Frodigh et al., U.S. Patent No. 6,125,148 (hereinafter *Frodigh*). Claims 13 and 21 were rejected under 35 U.S.C. § 103(a) as being unpatentable over *Palm* in view of *Frodigh*. Claims 14-17 and 22-24 were rejected under 35 U.S.C. § 103(a) as being unpatentable over *Palm* in view of *Frodigh* as applied to claims 13 and 21 above, and further in view of Barber et al.

Claims 1, 2, 4, 6, 9, 11, 12, 14, 17, 19, 20, 22, and 24 are amended as shown above. Specifically, independent claims 1, 11, and 19 are amended to more clearly recite features of the claimed invention. Claims 5, 13, 16, 21 and 23 are canceled herein without prejudice. Thus, claims 1-4, 6-12, 14, 15, 17-20, 22, and 24 are now pending in the application. For the reasons set forth below, the Applicants respectfully request reconsideration and allowance of all pending claims.

Argument in Support of Allowance over Claim Rejections under 35 U.S.C. § 103

To establish a *prima facie* case of obviousness, there must first be some suggestion or motivation to modify a reference or to combine references, and second be a reasonable expectation of success. The teaching or suggestion to make the claimed combination and the reasonable expectation of success must both be found in the prior art and not based on applicant's disclosure. Third, the prior art reference (or references when combined) must teach or suggest all the claim limitations. M.P.E.P. § 706.02(j) from *In Re Vaeck*, 947 F.2d 488, 20 USPQ2d 1438 (Fed. Cir. 1991). Where claimed subject matter has been rejected as obvious in view of a combination of prior

art references, a proper analysis under § 103 requires, *inter alia*, consideration of two factors: (1) whether the prior art would have suggested to those of ordinary skill in the art that they should make the claimed device; and (2) whether the prior art would also have revealed that in so making, those of ordinary skill would have a reasonable expectation of success. Both the suggestion and the reasonable expectation of success must be founded in the prior art, not in the Applicants' disclosure. *Amgen v. Chugai Pharmaceutical*, 927 F.2d 1200, 18 USPQ2d 1016 (Fed. Cir. 1991), *Fritsch v. Lin*, 21 USPQ2d 1731 (Bd. Pat. App. & Int'f 1991). An invention is non-obvious if the references fail not only to expressly disclose the claimed invention as a whole, but also to suggest to one of ordinary skill in the art modifications needed to meet all the claim limitations. *Litton Industrial Products, Inc. v. Solid State Systems Corp.*, 755 F.2d 158, 164, 225 USPQ 34, 38 (Fed. Cir. 1985).

The examiner must present a convincing line of reasoning as to why the artisan would have found the claimed invention to have been obvious in light of the teachings of the references. M.P.E.P. § 70602(j) from *Ex parte Clapp*, 227 USPQ 972, 973 (Bd. Pat. App. & Inter. 1985). Obviousness cannot be established by combining references without also providing evidence of the motivating force which would impel one skilled in the art to <u>do what the patent applicant has done</u>. M.P.E.P. § 2144 from *Ex parte Levengood*, 28 USPQ2d 1300, 1302 (Bd. Pat. App. & Inter. 1993) (emphasis added by M.P.E.P.).

Each of independent claims 1, 11, and 19 have been amended to incorporate subject matter that was previously recited in respective dependent claims 5, 13, and 21, which have been cancelled herein. Accordingly, the elements and limitations of these amended independent claims reflect similar elements and limitations in original claims 5, 13, and 21. In addition, each of these independent claims has been amended to reflect that the broadband signal that is received is a broadband cable signal.

Each of claims 13, and 21 were rejected under 35 U.S.C. § 103(a) as being unpatentable over *Palm* in view of *Frodigh.* It is noted that the amendment to claim 1 now recites elements and limitations contained in original claim 5, but does not include elements recited in original claim 4, from which original claim 5 depended. More specifically, amended claim 1 recites elements and limitations found in each of original claims 13 (having a base claim 11) and 21 (having a base claim 19). By analogy, it is reasoned that if original claim 5 was dependent on claim 1 rather than claim 4, this claim would have been rejected under 35 U.S.C. § 103(a) as being unpatentable over *Palm* in view of *Frodigh* as well. Accordingly, the following argues why each of amended claims 1, 11, and 19 is patentable over *Palm* in view of *Frodigh.*

By way of example, claim 1 has been amended to now recite;

1. A method comprising:

tuning a receiver of a broadband cable signal to a channel within the broadband cable signal to receive information including one or more cable modem operating parameters, *the broadband cable signal associated with a first modulation technique*;

temporarily modifying receiver parameters to demodulate the channel according to a second modulation technique that differs from the first modulation technique associated with the broadband cable signal;

recovering information contained within the demodulated signal corresponding to the one or more operating characteristics of the cable modem; and

updating one or more operating parameters of the cable modem in accordance with the received information.

Applicants respectfully assert that the combination of *Palm* and *Frodigh* do not meet all three prongs of the *In Re Vaeck* test with respect to supporting an obviousness rejection of amended claim 1.

As stated by its title, the *Palm* reference pertains to "Activation of multiple xDSL modems with channel probe." As stated in the Abstract, *Palm* discloses a,

> Method and apparatus for enabling data communication. The quality of a communication channel is determined using line probing techniques. In addition, capabilities of the communication devices are exchanged between a central location and a remote location. Based upon the quality of the communication channel, and the capabilities of the communication channel, an appropriate communication standard is selected.

In further detail, *Palm* discloses techniques for determining capabilities of an xDSL communication channel that is employed for communication between a central location and a remote location using an xDSL signal. As stated in the attached Cisco reference,

> Digital Subscriber Line (DSL) technology is a modem technology that uses existing twisted-pair telephone lines to transport high-bandwidth data, such as multimedia and video, to service subscribers. The term *xDSL* covers a number of similar yet competing forms of DSL technologies, including ADSL, SDSL, HDSL, HDSL-2, G.SHDL, IDSL, and VDSL. xDSL is drawing significant attention from implementers and service providers because it promises to deliver high-bandwidth data rates to dispersed locations with relatively small changes to the existing telco infrastructure.
>
> xDSL services are dedicated, point-to-point, public network access over twisted-pair copper wire on the local loop (last mile) between a network service provider's (NSP) central office and the customer site, or on local loops created either intrabuilding or intracampus. Currently, most DSL deployments are ADSL, mainly delivered to residential customers.

As stated in the first paragraph of the Summary of the Invention section,

> ... the overall purpose of the present invention is to develop a communication method, modem device and a data communication system that detects various configurations, capabilities and limitations of a communication channel and associated equipment in order to determine a specific (xDSL) communication standard appropriate for the existing line conditions. To accomplish this goal, the invention employs several individual techniques as a system.

The Applicant does not disagree with the characterization the Examiner makes above with respect to how *Palm*'s system operates. However, the Applicant respectfully asserts that the techniques disclosed by *Palm* are not applicable to broadband cable signals.

The general purpose of the various embodiments of the present application is to identify data channels from amongst multiple channels employed in a cable system. As stated in the Background section on page 3, lines 9-12, "Given the typical implementation of 6MHz channels over a spectrum of 91-857MHz, one of the problems cable modems have is identifying which of the over 125 channels in the broadband signal are data channels, and which are allocated to other programming (*e.g.*, A/V) channels." Over the lifetime of a cable system, it is most likely that the operator will reassign use of various channels within the cable broadband signal bandwidth for different purposes. For example, it is common for a cable operator to reassign given cable programming, such as ESPN, Discovery Channel, etc., to a different cable channel (*e.g.*, one of the over 125 channels discussed above).

In particular, the claims for the present application concern the aspect of recovering information including one or more cable modem operating parameters from a broadband cable signal and then updating corresponding cable modem operating parameters. This is made difficult, in part, because of the structure of a broadband cable signal, which differs significantly from the xDSL signals used by the *Palm* apparatus.

Typical cable channel usage includes both analog channels (*e.g.*, used to carry TV broadcast content in analog form), and digital channels (used to carry TV broadcast content in digital form, as well as carrying additional digital content such as the content used for displaying electronic program guides and the like). In addition to these types of channels, a portion of cable broadband signal channels are used as data channels via which data can be sent over cable system infrastructure using a cable modem. As with the analog and digital cable programming channels, the channels assigned for data channels may change over time. When such changes occur, it is advantageous for the cable modems to ascertain which channels are available as data channels as soon as practical so that those channels may be accessed for both uplink and downlink

purposes. As discussed in the Background section of the present application, conventional techniques for ascertaining the data channels include a brute force scheme under which each of the channels is examined by demodulating the content to determine whether the channel is a data channel, which often requires over a minute to complete. (Consider that under a conventional approach, both a digital channel and data channel appear the same).

In sharp contrast, the *Palm* reference concerns xDSL channels to be employed in xDSL broadband signals. An xDSL broadband signal is clearly not equivalent to a cable broadband signal. Details of the format of xDSL signals under the carrierless amplitude/phase (CAP) system and under the more common discrete multitone (DMT) system are illustrated in the attached talkbroadband.com web page printout. While an xDSL broadband signal arguably carries voice information and data, the voice information is always assigned to the "channel" from 0-4KHz, and the entire portion of the signal bandwidth above 4KHz is assigned to data channels under both the CAP and DMT schemes. As such, information to be transferred to an xDSL modem may be simply received via an xDSL data channel and encoded in a normal manner.

As further recited in claim 1, the broadcast cable signal is associated with a first modulation technique, and receiver parameters are temporarily modified to demodulate the channel according to a second modulation technique that differs from the first modulation technique. What this allows is for information (e.g., cable modem operating parameters) to be delivered "on top" of an existing broadcast cable signal channel without disturbing reception of the underlying channel content (such as an analog or digital audio/video signal). To encode this information, a second modulation scheme is used that is different from the normal modulation technique employed for the broadband cable signal. To decode this information, receiver parameters are temporarily modified to demodulate the overlying data portion of the channel.

In support of the rejection of original claims 13 and 21 (and claim 5 by way of analogy), the Examiner asserts that such elements are taught by *Frodigh*. Applicant respectfully disagrees. More specifically, the Examiner states, "Frodigh et al disclose a communication system wherein a traffic channel and a control channel (i.e., information channel) are modulated/demodulated using different techniques." While this may or may not be true, it doesn't read on the foregoing claim element with respect to temporarily modifying receiver parameters to demodulate the channel corresponding to a second demodulation technique. In fact, it is quite clear that *Frodigh* teaches away from modifying receiver parameters for such a purpose, as the *Frodigh* method and system employ but a single demodulator to support multiple modulation schemes.

As stated in the abstract, *Frodigh* discloses,

> A method of *demodulating* voice or data and control information in systems that support multiple modulation schemes modulates voice or data using a first linear modulation scheme, such as 16QAM modulation scheme, and modulates control information using a second linear modulation scheme, for example, QPSK modulation scheme, that has the same symbol rate as that of the first modulation scheme. The first linear modulation scheme has a higher modulation level than the second linear modulation scheme. Information modulated using the second linear modulation scheme, which uses a reduced signal set of the first linear modulation scheme, *are demodulated using <u>the same demodulator</u> that is used for demodulating information modulated using the first linear modulation scheme*. Also, in-band signalling information within a traffic channel, such as stealing flags, are modulated using the second modulation scheme. (Emphasis added)

As further stated in the first two paragraphs of the Summary section in column 3,

> The present invention that addresses this need is exemplified in a method of demodulating variously modulated information *<u>using an identical demodulator</u>* in systems that support multiple modulation schemes.
>
> Briefly, according to the method of the invention, voice or data is communicated over a traffic channel using a first linear modulation scheme, such as 16QAM modulation scheme. The traffic channel has an associated control channel that uses a second linear modulation scheme for communicating associated control information. In an exemplary embodiment, the second linear modulation scheme is a QPSK modulation scheme. The second linear modulation scheme, which has a lower level

> of modulation relative to the first modulation scheme, uses a reduced signal set of the first modulation scheme to communicate voice or data and control information. In this way, *the present invention uses the same demodulator to demodulate signals modulated using the second linear modulation scheme as that used to demodulate signals modulated using the first linear modulation scheme*. (Emphasis added)

It is clear from above, that the same, identical demodulator is used for demodulating both the first and second modulation scheme. Furthermore, the same demodulator is configured such that it can demodulate both types of modulation schemes simultaneously on an ongoing basis. Thus, under *Frodigh* there is no modification of receiver parameters that are employed to demodulate a signal that employs a second modulation technique that differs from a first modulation technique, nor would someone of ordinary skill in the art be motivated to do so in view of the *Frodigh* reference.

In view of the foregoing, it is clear that the combination of *Palm* and *Frodigh* do not teach or fairly suggest each and every element of independent claim 1, thus failing at least the third prong of the *In Re Vaeck* test. Applicant also respectfully asserts there would be no motivation to combine these two references to obtain the claimed invention, nor any expectation of success.

First of all, *Palm* pertains to xDSL signals, and Prodigh pertains to wireless digital signals used by cellular networks, while the claimed invention pertains to broadband cable signals. As discussed above, broadband cable signals are significantly different than xDSL signals. They are also different than wireless digital signals used by cellular networks. In a similar manner to xDSL signals above 4 KHz, all of the signals used for wireless digital signals contain digitized data in one form or another (e.g., encoded voice data is still data), and thus all effective “channels” in wireless digital signals are data channels. As a result, there would no need to encode cable modem operating parameters over another channel carrying different underlying digitized data or analog content – one could simply use one of the data channels to provide such data. This is

particularly true for cellular network channels, where each channel has a temporal existence (it must be reestablished for each new cellular connection and torn down after the connection is no longer in use), and the bulk of channels are not assigned to a particular purpose, such as delivering broadcast content corresponding to a particular broadcast channel, as is common to a broadband cable signal.

In view of the foregoing argument, it is clear that amended independent claim 1 is patentable over the combination of *Palm* and *Frodigh*. Additionally, each of independent claims 11 and 19 has been amended to include similar elements to those recited in amended claim 1. Accordingly, each of claims 11 and 19 is likewise patentable over *Palm* and *Frodigh* for similar reasons to those presented above in support of the patentability of claim 1. Moreover, each of dependent claims 2-4, 6-10, 12, 14, 15, 17, 18, 20, 22, and 24 is patentable for at least the same reasons as its respective base claim.

Overall, none of the references singly or in any motivated combination disclose, teach, or suggest what is recited in the independent claims. Thus, given the above amendments and accompanying remarks, independent claims 1, 11, and 19 are now in condition for allowance. The dependent claims that depend directly or indirectly on these independent claims are likewise allowable based on at least the same reasons and based on the recitations contained in each dependent claim.

If the undersigned attorney has overlooked a teaching in any of the cited references that is relevant to the allowability of the claims, the Examiner is requested to specifically point out where such teaching may be found. Further, if there are any informalities or questions that can be addressed via telephone, the Examiner is encouraged to contact the undersigned attorney at (206) 292-8600.

Charge Deposit Account

Please charge our Deposit Account No. 02-2666 for any additional fee(s) that may be due in this matter, and please credit the same deposit account for any overpayment.

Respectfully submitted,

BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN

Date: May 20, 2005

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In the Drawings

Please replace the original drawing sheet for Figure 1 with the attached replacement sheet. In the replacement sheet, the term “prior art” has been added to the figure number as requested by the Examiner.

Please replace the original drawing sheet for Figures 7A and 7B with the attached replacement sheet. In the replacement sheet, the spelling of the term baseband in block 706 of Figure 7A has been corrected.

Documentation

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Chapter Goals

- Identify and discuss different types of digital subscriber line (DSL) technologies.
- Discuss the benefits of using xDSL technologies.
- Explain how ASDL works.
- Explain the basic concepts of signaling and modulation.
- Discuss additional DSL technologies (SDSL, HDSL, HDSL-2, G.SHDSL, IDSL, and VDSL).

Digital Subscriber Line

Introduction

Digital Subscriber Line (DSL) technology is a modem technology that uses existing twisted-pair telephone lines to transport high-bandwidth data, such as multimedia and video, to service subscribers. The term *xDSL* covers a number of similar yet competing forms of DSL technologies, including ADSL, SDSL, HDSL, HDSL-2, G.SHDL, IDSL, and VDSL. xDSL is drawing significant attention from implementers and service providers because it promises to deliver high-bandwidth data rates to dispersed locations with relatively small changes to the existing telco infrastructure.

xDSL services are dedicated, point-to-point, public network access over twisted-pair copper wire on the local loop (last mile) between a network service provider's (NSP) central office and the customer site, or on local loops created either intrabuilding or intracampus. Currently, most DSL deployments are ADSL, mainly delivered to residential customers. This chapter focus mainly on defining ADSL.

Asymmetric Digital Subscriber Line

Asymmetric Digital Subscriber Line (ADSL) technology is asymmetric. It allows more bandwidth downstream—from an NSP's central office to the customer site—than upstream from the subscriber to the central office. This asymmetry, combined with always-on access (which eliminates call setup), makes ADSL ideal for Internet/intranet surfing, video-on-demand, and remote LAN access. Users of these applications typically download much more information than they send.

ADSL transmits more than 6 Mbps to a subscriber and as much as 640 kbps more in both directions (shown in Figure 21-1). Such rates expand existing access capacity by a factor of 50 or more without new cabling. ADSL can literally transform the existing

CHAPTER 21

Chapter Goals

- Identify and discuss different types of digital subscriber line (DSL) technologies.
- Discuss the benefits of using xDSL technologies.
- Explain how ASDL works.
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- Discuss additional DSL technologies (SDSL, HDSL, HDSL-2, G.SHDSL, IDSL, and VDSL).

Digital Subscriber Line

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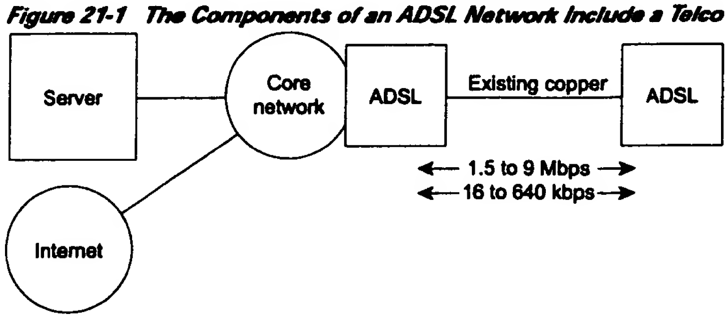
ADSL transmits more than 6 Mbps to a subscriber and as much as 640 kbps more in both directions (shown in Figure 21-1). Such rates expand existing access capacity by a factor of 50 or more without new cabling. ADSL can literally transform the existing public information network from one limited to voice, text, and low-resolution graphics to a powerful, ubiquitous system capable of bringing multimedia, including full-motion video, to every home this century.

Figure 21-1 The Components of an ADSL Network Include a Telco and a CPE



ADSL will play a crucial role over the next decade or more as telephone companies enter new markets for delivering information in video and multimedia formats. New broadband cabling will take decades to reach all prospective subscribers. Success of these new services depends on reaching as many subscribers as possible during the first few years. By bringing movies, television, video catalogs, remote CD-ROMs, corporate LANs, and the Internet into homes and small businesses, ADSL will make these markets viable and profitable for telephone companies and application suppliers alike.

ADSL Capabilities

An ADSL circuit connects an ADSL modem on each end of a twisted-pair telephone line, creating three information channels: a high-speed downstream channel, a medium-speed duplex channel, and a basic telephone service channel. The basic telephone service channel is split off from the digital modem by filters, thus guaranteeing uninterrupted basic telephone service, even if ADSL fails. The high-speed channel ranges from 1.5 to 9 Mbps, and duplex rates range from 16 to 640 kbps. Each channel can be submultiplexed to form multiple lower-rate channels.

ADSL modems provide data rates consistent with North American T1 1.544 Mbps and European E1 2.048 Mbps digital hierarchies (see Figure 21-2), and can be purchased with various speed ranges and capabilities. The minimum configuration provides 1.5 or 2.0 Mbps downstream and a 16-kbps duplex channel; others provide rates of 6.1 Mbps and 64 kbps for duplex. Products with downstream rates up to 8 Mbps and duplex rates up to 640 kbps are available today. ADSL modems accommodate Asynchronous Transfer Mode (ATM) transport with variable rates and compensation for ATM overhead, as well as IP protocols.

Figure 21-2 This Chart Shows the Speeds for Downstream Bearer and Duplex Bearer Channels

Downstream bearer channels	
n x 1.536 Mbps	1.536 Mbps 3.072 Mbps 4.608 Mbps 6.144 Mbps
n x 2.048 Mbps	2.048 Mbps 4.096 Mbps
Duplex bearer channels	
C channel	16 Kbps 64 Kbps
Optional channels	160 Kbps 384 Kbps 544 Kbps 576 Kbps

Downstream data rates depend on a number of factors, including the length of the copper line, its wire gauge, the presence of bridged taps, and cross-coupled interference. Line attenuation increases with line length and frequency, and decreases as wire diameter increases. Ignoring bridged taps, ADSL performs as shown in Table 21-1.

Table 21-1 Claimed ADSL Physical-Media Performance

Data Rate (Mbps)	Wire Gauge (AWG)	Distance (feet)	Wire Size (mm)	Distance (km)
1.5 or 2	24	18,000	0.5	5.5
1.5 or 2	26	15,000	0.4	4.6
6.1	24	12,000	0.5	3.7
6.1	26	9,000	0.4	2.7

Although the measure varies from telco to telco, these capabilities can cover up to 95 percent of a loop plant, depending on the desired data rate. Customers beyond these distances can be reached with fiber-based digital loop carrier (DLC) systems. As these DLC systems become commercially available, telephone companies can offer virtually ubiquitous access in a relatively short time.

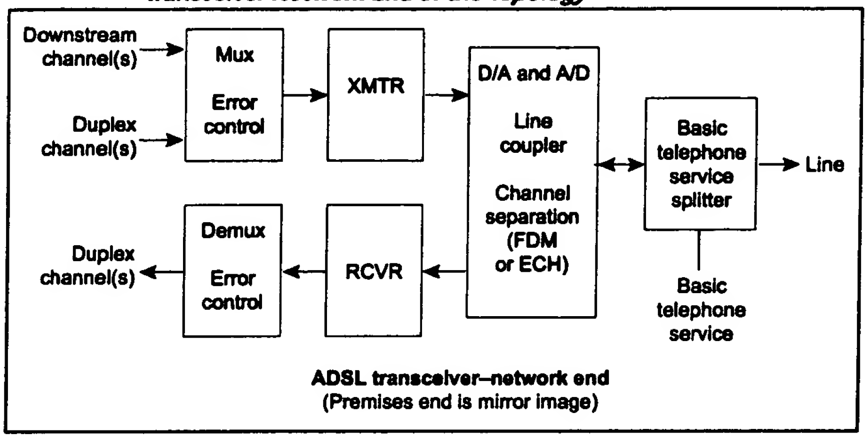
Many applications envisioned for ADSL involve digital compressed video. As a real-time signal, digital video cannot use link- or network-level error control procedures commonly found in data communications systems. Therefore, ADSL modems incorporate forward error correction that dramatically reduces errors caused by impulse noise. Error correction on a symbol-by-symbol basis also reduces errors caused by continuous noise coupled into a line.

ADSL Technology

ADSL depends on advanced digital signal processing and creative algorithms to squeeze so much information through twisted-pair telephone lines. In addition, many advances have been required in transformers, analog filters, and analog/digital (A/D) converters. Long telephone lines may attenuate signals at 1 MHz (the outer edge of the band used by ADSL) by as much as 90 dB, forcing analog sections of ADSL modems to work very hard to realize large dynamic ranges, separate channels, and

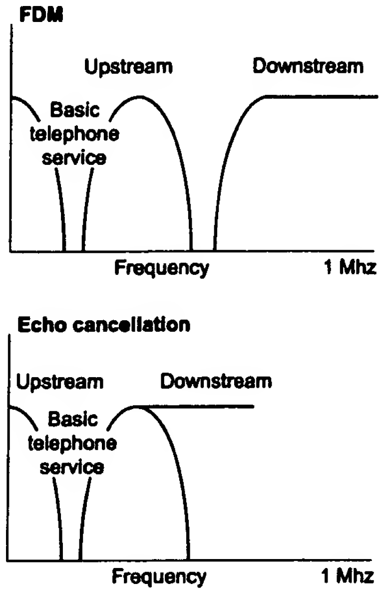
maintain low noise figures. On the outside, ADSL looks simple—transparent synchronous data pipes at various data rates over ordinary telephone lines. The inside, where all the transistors work, is a miracle of modern technology. Figure 21-3 displays the ADSL transceiver-network end.

Figure 21-3 This Diagram Provides an Overview of the Devices That Make Up the ADSL Transceiver-Network End of the Topology



To create multiple channels, ADSL modems divide the available bandwidth of a telephone line in one of two ways: frequency-division multiplexing (FDM) or echo cancellation, as shown in Figure 21-4. FDM assigns one band for upstream data and another band for downstream data. The downstream path is then divided by time-division multiplexing into one or more high-speed channels and one or more low-speed channels. The upstream path is also multiplexed into corresponding low-speed channels. Echo cancellation assigns the upstream band to overlap the downstream, and separates the two by means of local echo cancellation, a technique well known in V.32 and V.34 modems. With either technique, ADSL splits off a 4-kHz region for basic telephone service at the DC end of the band.

Figure 21-4 ADSL Uses FDM and Echo Cancellation to Divide the Available Bandwidth for Services



An ADSL modem organizes the aggregate data stream created by multiplexing downstream channels, duplex channels, and maintenance channels together into blocks, and it attaches an error correction code to each block. The receiver then corrects errors that occur during transmission, up to the limits implied by the code and the block length. At the user's option, the unit also can create superblocks by interleaving data within subblocks; this allows the receiver to correct any combination of errors within a specific span of bits. This, in turn, allows for effective transmission of both data and video signals.

Signaling and Modulation

This section includes the following:

- CAP and DMT Modulated ADSL
- ADSL Standards and Associations

CAP and DMT Modulated ADSL

DMT and *CAP* are line-coding methods for modulating the electrical signals sent over the copper wire in the local loop. Carrierless Amplitude and Phase (CAP) is a common line-coding method. CAP is a well-understood technology because of its similarity with QAM. Although CAP is well-understood and relatively inexpensive, some argue that it is difficult to scale because it is a single-carrier modulation technique and is susceptible to narrowband interference. DMT uses multiple carriers. At this point, DMT is capable of more speed than CAP. This is one reason that the ANSI committee T1E1.4 accorded it standards status in document T1.413.

This standard calls for 256 subbands of 4 KHz each, thereby occupying 1.024 GHz. Each subband can be modulated with QAM 64 for clean subbands, down to QPSK. If each of the subbands can support QAM-64 modulation, then the forward channel supports 6.1 Mbps. On the return path are 32 subbands, with a potential for 1.5 Mbps.

CAP and DMT Compared

CAP is a single-carrier technique that uses a wide passband. DMT is a multiple-carrier technique that uses many narrowband channels. The two have a number of engineering differences, even though, ultimately, they can offer similar service to the network layers discussed previously.

Adaptive Equalization

Adaptive equalizers are amplifiers that shape frequency response to compensate for attenuation and phase error. Adaptive equalization requires that the modems learn line characteristics and do so by sending probes and looking at the return signals. The equalizer then knows how it must amplify signals to get a nice, flat frequency response. The greater the dynamic range, the more complex the equalization. ADSL requires 50 dB of dynamic range, complicating adaptive equalization. Only with recent advances in digital signal processing (number crunching) has it become possible to have such equalization in relatively small packaging.

Adaptive equalization is required for CAP because noise characteristics vary significantly across the frequency passband. Adaptive equalization is not needed for DMT because noise characteristics do not vary across any given 4-KHz subband. A major issue in comparing DMT with CAP is determining the point at which the complexity of adaptive equalization surpasses the complexity of DMT's multiple Fourier transform calculations. This is determined by further implementation experience.

Power Consumption

Although DMT clearly scales and does not need adaptive equalization, other factors must be considered. First, with 256 channels, DMT has a disadvantage regarding power consumption (and, therefore, cost) when compared with CAP. DMT has a high peak-to-average power ratio because the multiple carriers can constructively interfere to yield a strong signal. DMT has higher computational requirements, resulting in more transistors than the transceiver chips. Numbers are mostly proprietary at this point, but it is estimated that a single transceiver will consume 5 W of power, even with further advances. Power consumption is important because hundreds or thousands (as carriers dearly hope) of transceivers might be at the central office, or CEV. This would require much more heat dissipation than CAP requires.

Latency

Another issue for DMT is that latencies are somewhat higher than with CAP (15). Because each subband uses only 4 KHz, no bit can travel faster than permitted by a QAM-64. The trade-off between throughput and latency is a historical one in data communications and has normally been settled in the marketplace.

Speed

DMT appears to have the speed advantage over CAP. Because narrow carriers have relatively few equalization problems, more aggressive modulation techniques can be used on each channel. For CAP to achieve comparable bit rates, it might be necessary to use more bandwidth, far beyond 1 MHz. This creates new problems associated with high frequencies on wires and would reduce CAP's current advantage in power consumption.

ADSL Standards and Associations

The American National Standards Institute (ANSI) Working Group T1E1.4 recently approved an ADSL standard at rates up to 6.1 Mbps (DMT/ANSI Standard T1.413). The European Technical Standards Institute (ETSI) contributed an annex to T1.413 to reflect European requirements. T1.413 currently embodies a single terminal interface at the premises end. Issue II expands the standard to include a multiplexed interface at the premises end, protocols for configuration and network management, and other improvements.

The ATM Forum and the Digital Audio-Visual Council (DAVIC) have both recognized ADSL as a physical layer transmission protocol for UTP media.

Additional DSL Technologies

This section discusses the following DSL technologies:

- SDSL
- HDSL
- HDSL-2
- G.SHDSL
- ISDN Digital Subscriber Line (DSL)
- VDSL

SDSL

Symmetric Digital Subscriber Line (SDSL) is a rate-adaptive version of HDSL and, like HDSL, is symmetric. It allows equal bandwidth downstream from an NSP's central office to the customer site as upstream from the subscriber to the central office. SDSL supports data only on a single line and does not support analog calls. SDSL uses 2B1Q line coding and can transmit up to 1.54 Mbps to and from a subscriber, or can be configured to offer a variable range of bandwidth up to 1.45 Mbps.

The symmetry that SDSL offers, combined with always-on access (which eliminates call setup), makes it a favorable WAN technology for small to medium businesses and branch offices, and can be an affordable alternative to dedicated leased lines and Frame Relay services. Because traffic is symmetrical, file transfer, web hosting, and distance-learning applications can effectively be implemented with SDSL.

HDSL

Originally developed by Bellcore, high bit-rate DSL (HDSL)/T1/E1 technologies have been standardized by ANSI in the United States and by ETSI in Europe. The ANSI standard covers two-pair T1 transmission, with a data rate of 784 kbps on each twisted pair. ETSI standards exist both for a two-pair E1 system, with each pair carrying 1168 kbps, and a three-pair E1 system, with 784 kbps on each twisted pair.

HDSL became popular because it is a better way of provisioning T1 or E1 over twisted-pair copper lines than the long-used technique known as Alternative Mark Inversion (AMI). HDSL uses less bandwidth and requires no repeaters up to the CSA range. By using adaptive line equalization and 2B1Q modulation, HDSL transmits 1.544 Mbps or 2.048 Mbps in bandwidth ranging from 80ntrast to the 1.5 MHz required by AMI. (AMI is still the encoding protocol used for the majority of T1.)

T1 service can be installed in a day for less than $1,000 by installing HDSL modems at each end of the line. Installation via AMI costs much more and takes more time because of the requirement to add repeaters between the subscriber and the CO. Depending on the length of the line, the cost to add repeaters for AMI could be up to $5,000 and could take more than a week.

HDSL is heavily used in cellular telephone buildouts. Traffic from the base station is backhauled to the CO using HDSL in more than 50 percent of installations. Currently, the vast majority of new T1 lines are provisioned with HDSL. However, because of the embedded base of AMI, less than 30 percent of existing T1 lines are provisioned with HDSL.

HDSL does have drawbacks. First, no provision exists for analog voice because it uses the voice band. Second, ADSL achieves better speeds than HDSL because ADSL's asymmetry deliberately keeps the crosstalk at one end of the line. Symmetric systems such as HDSL have crosstalk at both ends.

HDSL-2

HDSL-2 is an emerging standard and a promising alternative to HDSL. The intention is to offer a symmetric service at T1 speeds using a single-wire pair rather than two pairs. This will enable it to operate for a larger potential audience. It will require more aggressive modulation, shorter distances (about 10,000 feet), and better phone lines.

Much of the SDSL equipment in the market today uses the 2B1Q line code developed for Integrated Services Digital Network. The Bell companies have insisted that using this SDSL at speeds higher than 768 kbps can cause interference with voice and other services that are offered on copper wire within the same wire bundle.

The biggest advantage of HDSL-2, which was developed to serve as a standard by which different vendors' equipment could interoperate, is that it is designed not to interfere with other services. However, HDSL-2 is full rate only, offering services only at 1.5 Mbps.

G.SHDSL

G.SHDSL is a standards-based, multirate version of HDSL-2 and offers symmetrical service. The advantage of HDSL-2, which was developed to serve as a standard by which different vendors' equipment could interoperate, is that it is designed not to interfere with other services. However, the HDSL-2 standard addresses only services at 1.5 Mbps. Multirate HDSL-2 is part of Issue 2 of the standard known as G.SHDSL, and is ratified by the ITU. G.SHDSL builds upon the benefits of HDSL-2 by offering symmetrical rates of 2.3 Mbps.

ISDN Digital Subscriber Line

ISDN digital subscriber line (IDSL) is a cross between ISDN and xDSL. It is like ISDN in that it uses a single-wire pair to transmit full-duplex data at 128 kbps and at distances of up to RRD range. Like ISDN, IDSL uses a 2B1Q line code to enable transparent operation through the ISDN "U" interface. Finally, the user continues to use existing CPE (ISDN BRI terminal adapters, bridges, and routers) to make the CO connections.

The big difference is from the carrier's point-of-view. Unlike ISDN, ISDL does not connect through the voice switch. A new piece of data communications equipment terminates the ISDL connection and shuts it off to a router or data switch. This is a key feature because the overloading of central office voice switches by data users is a growing problem for telcos.

The limitation of ISDL is that the customer no longer has access to ISDN signaling or voice services. But for Internet service providers, who do not provide a public voice service, ISDL is an interesting way of using POTS dial service to offer higher-speed Internet access, targeting the embedded base of more than five million ISDN users as an initial market.

VDSL

Very-High-Data-Rate Digital Subscriber Line (VDSL) transmits high-speed data over short reaches of twisted-pair copper telephone lines, with a range of speeds depending on actual line length. The maximum downstream rate under consideration is between 51 and 55 Mbps over lines up to 1000 feet (300 m) in length. Downstream speeds as low as 13 Mbps over lengths beyond 4000 feet (1500 m) are also common. Upstream rates in early models will be asymmetric, just like ADSL, at speeds from 1.6 to 2.3 Mbps. Both data channels will be separated in frequency from bands used for basic telephone service and Integrated Services Digital Network (ISDN), enabling service providers to overlay VDSL on existing services. Currently, the two high-speed channels are also separated in frequency. As needs arise for higher-speed upstream channels or symmetric rates, VDSL systems may need to use echo cancellation.

Summary

ASDL technology is asymmetric, allowing more bandwidth for downstream than upstream data flow. This asymmetric technology combined with always-on access makes ASDL ideal for users who typically download much more data than they send.

An ASDL modem is connected to both ends of a twisted-pair telephone line to create three information channels: a high-speed downstream channel, a medium-speed duplex channel, and a basic telephone service channel. ADSL modems create multiple channels by dividing the available bandwidth of a telephone line using either frequency-division multiplexing (FDM) or echo cancellation. Both techniques split off a 4-kHz region for basic telephone service at the DC end of the band

Synchronous Digital Subscriber Line (SDSL) provides variable, symmetric, high-speed data communication up to 1.54 Mbps. But SDSL doesn't allow analog on the same line, as ADSL does. SDSL uses 2B1Q line coding, a technology employed in ISDN and T1 services. SDSL is a viable business option because of its capability to transmit high-speed data over longer distances from the CO and because of its ease of deployment made possible by its spectral compatibility.

High Bit-Rate DSL (HDSL) is a symmetric version of DSL that uses 2B1Q like SDSL, but over two-wire pairs. HDSL is targeted at business deployment because it offers full-rate symmetrical 1.5 Mbps service. HDSL-2 is a standards-based version of HDSL offering symmetrical 1.5 Mbps service like HDSL, but with a single twisted pair of wires. HDSL is full-rate and does not offer variable rates.

G.SHDSL does offer multirate service with symmetrical speeds of up to 2.3 Mbps.

ISDN digital subscriber line (IDSL) is similar in many ways to ISDN. The primary difference is that IDSL is always on and can reach speeds up to 512 kbps with compression. IDSL uses 2B1Q line coding and does not support analog.

On the other hand, IDSL does allow data communications over longer distances than other DSL options (up to 26,000 feet) and is considerably less expensive than ISDN service, in most cases. Because IDSL supports existing ISDN CPE, it makes it easy to convert from ISDN to IDSL.

Very-High-Data-Rate Digital Subscriber Line (VDSL) transmits high-speed data over short distances through twisted-pair copper telephone lines. VDSL technology is still in the definition stage, but additional research is required before it can be standardized. VSDL and ADSL are similar technologies. However, although VSDL transmits data at nearly 10 times the rate of ADSL, ADSL is the more complex transmission technology.

Review Questions

Q—*Name the current versions of DSL technology.*

A— ADSL, SDSL, HDSL, HDSL-2, G.SHDL, IDSL, and VDSL.

Q—*What are the two-line coding methods used for ADSL?*

A—DMT and CAP.

Q—*Which versions of DSL offer symmetrical service?*

A—SDSL, HDSL, and HDSL-2.

Q—*What symmetrical version of DSL offers multirate service over a single pair of wire?*

A—G.SHDSL

Q—*How far of a reach can IDSL achieve from the CO?*

A—26,000 feet.

Q—*What downstream and upstream rates are proposed for VDSL?*

A—The maximum downstream rate under consideration is between 51 and 55 Mbps over lines up to 1000 feet (300 m) in length. Downstream speeds as low as 13 Mbps over lengths beyond 4000 feet (1500 m) are also common. Upstream rates in early models will be asymmetric, just like ADSL, at speeds from 1.6 to 2.3 Mbps.

For More Information

ADSL Forum (http://www.adsl.com/)

Cisco DSL Depot (http://www.cisco.com/warp/public/779/servpro/promotions/dsldepot/)

Glossary Terms

- **G.SHDSL**—Asymmetrical Digital Subscriber Line. The upstream data rate is different from the downstream (typically the downstream is greater than the upstream). It is applicable to many DSL technologies offered today; however, this term typically assumes DMT as defined in the ANSI T1.413 specification.
- **CPE**—Customer premises equipment, including devices such as CSU/DSUs, modems, and ISDN terminal adapters, required to provide an electromagnetic termination for wide-area network circuits before connecting to the router or access server. This equipment was historically provided by the telephone company, but it is now typically provided by the customer in North American markets.

- **CSU/DSU**—Channel service unit/data service unit. Provides electromagnetic termination of the digital (WAN) signal at the customer premises. Performs line conditioning and equalization functions, and responds to loopback commands sent from the central office. In North America, the customer supplies the device providing CSU/DSU functionality; outside North America, the telecommunications service provider usually provides this device.
- **DMT** —Discrete Multitone is the ANSI specified modulation technique for G.SHDSL (ANSI-T1.413). DMT is theoretically capable of more speed than CAP. The key providers of DMT are Alcatel, Amati, Aware/ADI, and Orckit.
- **Downstream**—Refers to the transmission of data from the central office (CO or COE) to the customer premise equipment (CPE).
- **HDSL**—High-speed Digital Subscriber Line. This is a symmetrical modulation technique that uses two or three pairs of wires.
- **HDSL2**—High-speed Digital Subscriber Line. This is a symmetrical modulation technique that can achieve speeds in the T1 (1.5 Mbps) range using one copper pair.
- **POTS** —Plain old telephone service.
- **QAM** —Quadrature amplitude phase modulation.
- **RG.SHDSL**—Rate Adaptive Digital Subscriber Line. This refers to the CAP2 and QAM technologies that use variable data rates to maximize the utilization of various loop lengths.
- **SDSL**—Symmetric Digital Subscriber Line. This indicates a subscriber line service that utilizes the same data rate for upstream and downstream. This term is applicable to MDSL and HDSL technologies.
- **Upstream**—Refers to the transmission of data from the customer premises equipment (CPE) to the central office equipment (CO or COE).
- **VDSL**—Very-High-Data-Rate Digital Subscriber Line. This is a high-speed asymmetrical service in the 10 to 25 Mbps range, typically limited to less than 5,000 feet. The targeted application for this technology is a hybrid fiber copper system (fiber to the neighborhood).

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May 9, 2005

Broadband Technology - How Does xDSL Work? [page 2]

KEY CABLE xDSL SAT

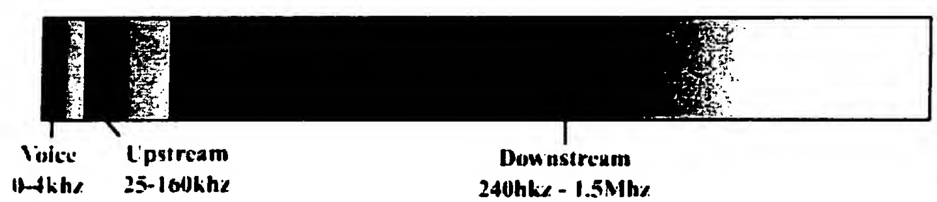
Technical Level: High

TalkBroadband - How Does xDSL Work?

The technology unraveled!

As we now know xDSL works by taking full advantage of the copper telephone wires we currently have installed by allowing a greater use of the bandwidth (or range of signals on the wires). The bandwidth that is available is many times greater than that used for our calls however it requires a particular method of signalling to safely utilise it. Currently there are two main types of technology that are competing for the xDSL standard, these are the discrete multitone (or DMT system) which is the most widely used technology and also the carrierless amplitude/phase (CAP) system, which was adopted on many original installations.

The CAP method works by taking the entire bandwidth of the copper wires and simply splitting them up into 3 distinct sections or bands seperated to alleviate interference. Each signal band is then allocated a particular task. The first band is in the signal range of 0 to 4 khz and is used for telephone conversations. The second band occupies the range of 25 to 160 khz which is used as an upstream channel, whilst the third band covers from 240 khz up to a maximum (depending on conditions) of 1.5 mhz and is used as a downstream channel. This method was simple and effective as poor quality wires or large amounts of interference wouldn't affect the xDSL from working, instead it would just limit the range of the third band and result in slightly reduced speeds.



xDSL CAP System
www.TalkBroadband.com

The DMT is system is much more complex. It works by splitting the entire frequency range (bandwidth) into 247 channels of 4 khz each and allocating a range of the lower channels, staring at around 8 khz, as bidirecitonal to provide upstream and downstream channels. By splitting the bandwidth up in this way it effectively allows one connection to operate as if there were 247 modems connected to it, each of which operating at 4 khz. The technology used in the DMT system is vasitly more complex than that required for the CAP method as each of the 247 channels requires constant monitoring and assessment. If the system

detects that a specific channel or range of channels are suffering from interference or a degredation in quality then the data stream must be automatically transferred to different channels. Finally, it is most likely that if you have the DMT system installed then you will need to place low pass filters into any telephone socket that you wish to make voice calls from. This is because voice calls take place below the 4 khz frequency and the filters simply block anything above this to prevent data signals interfering withe ur telephone call.

247 Unique Channels
4khz Each

xDSL DMT System
www.TalkBroadband.com

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